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Growth and Annulus Formation in Young-of-the-Year Rainbow Trout in Great Smoky Mountains National Park

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I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

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GROWTH AND ANNULUS FORMATION IN YOUNG-OF-THE-YEAR RAINBOW TROUT IN GREAT SMOKY MOUNTAINS NATIONAL PARK

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ABSTRACT

Age and growth studies of rainbow trout (*Oncorynchus mykiss*) have traditionally focused primarily on fish in the northeastern United States. Little research has been completed on trout at the southern margin of their distributions. This study was an attempt to determine (1) growth patterns, (2) time of annulus formation in scales and otoliths and their relations to growth patterns, and (3) percent agreement between scale age and otolith age in young-of-the-year (YOY) rainbow trout in Great Smoky Mountains National Park. Young-of-the-year rainbow trout were sampled monthly from September 1996 to September 1997. Total lengths and weights were recorded, and scales and otoliths were collected for analysis. Growth between March and June (spring) was significantly greater than other times of the year. Condition peaked in March at the beginning of this growth period. Annuli were observed on scales in March and April while annuli appeared on otoliths in April. Mean agreement between scales and otoliths for the study was 93.7%. These results suggest that rainbow trout in the southern Appalachians do not follow the growth patterns observed in other parts of the country; the majority of growth occurs in the spring, and there is little growth during the remainder of the year. This study and further examination of age and growth in the Southeast will provide fisheries biologists better information with which to make management decisions.

INTRODUCTION

Over the last fifty years, studies of age and growth in freshwater fish have greatly increased the understanding of growth patterns (Carlander 1987). Historical age and growth study has revealed that rainbow trout (*Oncorhynchus mykiss*) in mountain streams follow a development pattern where fish undergo the majority of their growth during the late spring, summer, and early fall (Beyerle and Cooper 1960). Salmonids in Great Smoky Mountains National Park (GSMNP), however, are at the southern margin of their distribution (Flebbe 1994). Trout distribution patterns are determined primarily by water temperatures which increase with decreasing latitude and elevation (Flebbe 1994). Recent data from the southern Appalachians indicate that these traditional growth patterns may not occur at the southern limit of rainbow trout. Cada et al. (1987) found that there is an inadequate food base during the summer. Consequently, growth rates slow because the limited energy consumed by the fish is used for metabolism. During the winter growth rates increase due to reduced energy requirements for metabolism in lower water temperatures. Ensign et al. (1990) also found that energy intake is used strictly for maintenance metabolism during the summer. Fisheries biologists in GSMNP have marked fish in Little River with visible implant tags since the spring of 1991 (see McMahon et al. 1996). Data from recovered fish further suggest that the traditional pattern of growth is not occurring in GSMNP. Instead, total length and weight changes from September to May were much greater than during the summer months (May to September), suggesting that fish are growing the most during the winter and spring (M. Kulp, GSMNP, personal communication). This information has led fisheries biologists to postulate that winter temperatures do not become cold enough to limit growth and, as a result, rainbow trout in the Park have different growth patterns than trout in the northeastern United States (M. Kulp and S. Moore, GSMNP, personal communication). This study is an attempt to define the growth patterns of YOY rainbow trout in GSMNP and determine when annuli on scales and otoliths are formed. Such information will allow fisheries biologists working with southern Appalachian rainbow trout to determine the best techniques and time of year to age fish and to devise appropriate management plans.

Specific objectives of this study were to determine (1) monthly growth patterns, (2) time of annulus formation in scales and otoliths, and (3) percent agreement between scales and otoliths for young-of-the-year rainbow trout in Great Smoky Mountains National Park.

METHODS

Study Design

Fish were collected from Little River between Milsaps parking area (approximately two miles downstream of Elkmont campground) and approximately one-half mile upstream of the campground. Little River is a fifth order stream in this area and elevations range from 640 meters (2100 feet) to 670 meters (2200 feet). Little River was chosen due to its accessibility in all seasons and its abundance of rainbow trout. The 1996 cohort in Little River was relatively strong and thus could be easily recognized and followed throughout the year (M. Kulp and S. Moore, GSMNP, personal communication). Size classes began to merge as the year progressed. A range including 1995 and 1997 year classes were collected to reduce bias.

Only scales were to be collected for analysis according to the original design. By the November sample it was determined that otoliths would provide additional validity to the study. Although otolith collection requires sacrificing the fish, otoliths have several advantages over scales. Otoliths are formed during the embryonic state, reflecting the entire growth of the fish, and they are never regenerated as scales often are (Jearld 1983). Beamish and McFarlane (1983) recommended that scales should be validated using some other hard structure as scales often show false annuli, which often lead to overestimation of ages. Any process that disrupts resources necessary for growth might cause a change in the hard tissue, known as a check, and the check may mistakenly be called an annulus (Busacker et al. 1990). Simkiss (1972) refers to the Crichton effect, where scales are resorbed during periods of stress. He found no evidence of resorption in otoliths, as they more readily utilize calcium. Carlander (1987) also recognized the need to examine otoliths and suggested the use of validation techniques whenever possible.

Fish Sampling

Approximately 25 fish were sampled monthly for 13 months (September 1996 through September 1997). Fish were collected using backpack electrofishing units operated at 600 volts AC. The trout were overdosed with tricaine methanesulfonate (MS-222). Total length (mm) and wet weight (g) of each individual were recorded.

Scales were collected just posterior to the dorsal fin, above the lateral line and placed in an indexed envelope (Jearld 1983). The scales were read without knowledge of fish lengths, using a microfiche projector (32x magnification). The development of the annulus was followed monthly. Scale radius (distance from focus to scale margin) was measured. On fish that had formed an annulus, the distance from the focus to the outer edge of the annulus was recorded. Four to six scales were measured from each fish, and these distances were averaged to obtain one value. Annular developments observed on the scales were carefully noted.

Otoliths, or earbones, were also collected. Fish have three pairs of otoliths on each side of the brain. The saggital pair is the standard choice because it is the largest and, therefore, the easiest to remove and read (Devries and Frie 1996). To remove the otoliths, the gill arches were cut away, and the otoliths were extracted from the base of the skull. They were stored dry in envelopes with the corresponding scales. The otoliths were also read whole and without knowledge of fish lengths in a black watch glass under a dissecting microscope with reflected light. A drop of oil was used to facilitate reading (Brothers 1987). Otoliths have alternating hyaline and opaque bands. The hyaline band represents active growth while the opaque bands represent slow growth. Together they represent one year of growth (Devries and Frie 1996). Annulus formation was followed monthly.

Fulton-type condition factors (K) were determined for each fish every month. Condition is an index of fish well-being and is expressed as

$$K = (W/L^3) \times 100{,}000$$

where W is weight, L is length, and 100,000 is a conversion factor (Anderson and Gutreuter 1983). The average monthly conditions were then compared and related to annulus formation.

Means and standard deviations were generated monthly for total length, weight, condition, and scale measurements (scale radius and annular distance). Monthly means for each parameter were then compared using one-way analysis of variance and Duncan's Multiple Range Test to determine significant differences ($p<0.05$).

Ages obtained from individual scales and otoliths were compared to determine agreement. Percent agreement between scales and otoliths was calculated for each month of the study.

RESULTS

Growth Patterns

The greatest period of growth for young-of-the-year rainbow trout occurred between the months of March and June (spring). There was little growth during the previous fall and winter (September 1996 to February) or the subsequent summer (July to September 1997).

Total Length

Duncan's Multiple Range Test showed statistically significant variation between several monthly mean total lengths (Figure 1). The greatest increase in length occurred from March to June. During this period total lengths increased significantly each month (97.4 ± 10.2 mm to 148.5 ± 16.6 mm). In February, mean total length dropped significantly (83.5 ± 8.1 mm). From June to September 1997 there was no significant increase in total length (148.5 ± 16.6 mm to 157.3 ± 13.6 mm)

Weight

Mean weights followed a trend similar to that for mean total lengths (Figure 2). Significant weight gains began in March and peaked in June (9.6 $\pm$ 2.5 g to 31.6 $\pm$ 11.2 g). From September 1996 to February, no significant increase in weight occurred (8.4 $\pm$ 3.6 g to 5.3 $\pm$ 1.6 g). Weights did not change significantly during the summer until September 1997 (38.9 $\pm$ 10.7 g). Standard deviations increased two to five times for the June through September 1997 samples.

Condition

Mean condition was typically between 0.90 and 1.00 during the study (Figure 3). The primary change occurred in March when condition reached its highest level (1.04 $\pm$ 0.12). A significant decrease was then observed in April, and there were no further significant changes in the remaining months.

Annulus Formation

Scales

Scales from 17 of the 28 fish collected in the March sample (60.7%) had developed an annulus (Figure 4). The April sample showed that 25 of the 28 sampled (89.0%) had formed an annulus (Figure 4). An annulus was visible on the remaining three scales, but there was not enough growth beyond the mark to consider it complete.

There was no significant variation in mean scale radii from September 1996 to February (Figure 5). Significant increases appeared monthly from March to June (23.4 $\pm$

2.2 to 39.1 ± 4.5) and then from July to September 1997 (40.8 ± 4.6 to 46.2 ± 4.6). Figure 5 also shows that mean annular distances increased significantly between April and May (22.4 ± 2.7 to 25.1 ± 2.5) and June and July (26.2 ± 3.7 to 27.7 ± 4.0)

Otoliths

Annuli were observed on all otoliths in April (Figure 6). None appeared prior to or after this month.

Agreement

Agreement between scale age and otolith age was nearly 100% throughout the year except during annulus formation in March (Figure 7). Mean agreement from November to February was 99.2%. Agreement between the structures then dropped to 63.0% in March due to the earlier appearance of annuli on the scales. In April, agreement improved to 88.5% as annuli were observed on the otoliths. Agreement was 100% for May and June. For the remainder of the study (July to September 1997), mean agreement was 94.3%. Mean agreement between scales and otoliths for the entire study was 93.7%.

DISCUSSION

These data are among the first to address the growth and annulus formation of rainbow trout in the southern Appalachians. The results indicate that YOY fish undergo the majority of their growth in the spring and do not increase significantly in length or weight during the summer or the winter. Annuli are formed on scales and otoliths prior to this period of growth.

Growth Patterns

Mean total lengths and weights markedly increased from March to June, the mildest time of the study period. Air temperatures had begun to warm after the winter months. During June, Little River experienced several flood events. July marked the beginning of a drought period, and discharge was much lower than normal. For example, stream flows at Milsaps and above Elkmont were 8.48 cfs and 13.69 cfs, respectively, in September 1997 compared with 57.31 cfs and 40.22 cfs in September 1996 (GSMNP unpublished data).

The large standard deviations for weight indicated that, although mean weights remained relatively constant, a broad range of weights was present. Growth rates of individual fish possibly became more variable within the sample in the summer months (June to September 1997). This range suggests that summer conditions (e.g. higher water temperatures) have a greater impact on weights of individual fish than on the lengths. The decrease in length and weight in February was caused by a sampling bias for smaller fish as it was necessary to restrict collection efforts to slower moving waters near the bands and in side channels.

Condition also reach peaked at the beginning of the fast growth period. The fish were healthy and were likely metabolically fit to begin rapid growth (Cada et al. 1987, Ensign et al. 1990). Otherwise, it is difficult to assess trends in condition for the rest of the study. In a growth study of southern Appalachian rainbow trout, Loar (1985) also found no consistent seasonal trends in condition at eight sites. Cada et al. (1987) found that mean condition of age-1 trout declined during the summer. Ensign et al. (1990)

discovered in a similar study that condition tended to be higher in June than in midsummer but generally recovered in late summer. These differing results point to the need to further investigate the seasonal patterns of condition and determine the factors that influence these values (e.g. water temperature, discharge, age, and food supply).

Annulus Formation

By April, both scales and otoliths had developed annuli. This formation marked the first anniversary of the appearance of these fish almost exactly. Rainbow trout in GSMNP spawn in March and emerge from the gravel in mid-April and May (S. Moore, GSMNP, personal communication). Annuli were laid down at a time of peak condition and just before rapid growth. The period of slow growth from June into September provoked questions concerning its effects on subsequent annulus development on scales and otoliths. For example, Laasko and Cope (1956) found that resumption of seasonal growth was delayed in older cutthroat trout in Yellowstone Lake and its connecting waters. Further studies of older fish will help to answer these questions.

Scale growth showed some interesting trends. As expected, scale radii increased as total lengths and weights increased from March to June. Then, a second increase began in August and continued into the September 1997 sample, while lengths and weights underwent little variation. Obtaining additional information from this cohort as it ages would reveal the effects, if any, such scale growth has on annulus development.

Agreement

Agreement between scales and otoliths was high for this study. Kulp (1993) also found a high level of agreement (98%) in his study on YOY brook trout in GSMNP. Agreement differences were more likely between scales and otoliths from older rainbow trout (i.e. age-2) that were incidentally collected. These discrepancies indicate that scale growth patterns may diverge from otolith patterns as the fish ages. Kulp (1993) reported that percent agreement dropped to 47% for age-3 brook trout and to 17% for age-4 fish.

There is an obvious need to study all age classes of rainbow trout to determine if and how the patterns of growth change throughout the life history of the fish. It is possible that YOY trout behave differently from older fish. This age class requires less food and perhaps is less limited by food availability than older classes are (Cada et al. 1987, Ensign et al. 1990); thus, YOY rainbow trout may not be affected by factors that affect slower growing, older fish. These data do indicate that the patterns of growth observed in the Northeast are not occurring in YOY fish in GSMNP and substantiate the growth patterns that Cada et al. (1987) and Ensign et al. (1990) observed. This information, in conjunction with further studies of older fish, will provide a better understanding of age and growth characteristics of rainbow trout in the southern Appalachians.

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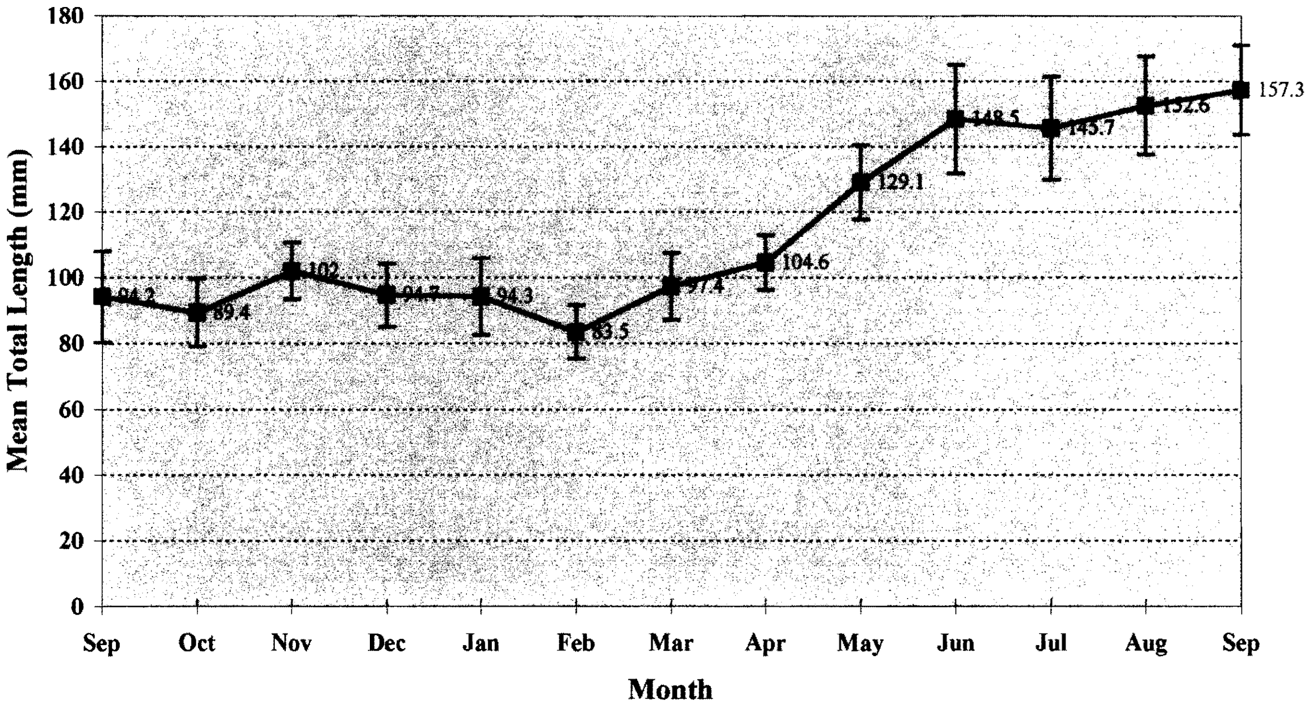

Figure 1. Mean total lengths (mm) of trout collected from September 1996 to September 1997 in Little River, GSMNP. Vertical bars represent standard deviation. Red points indicate significant change from previous month.

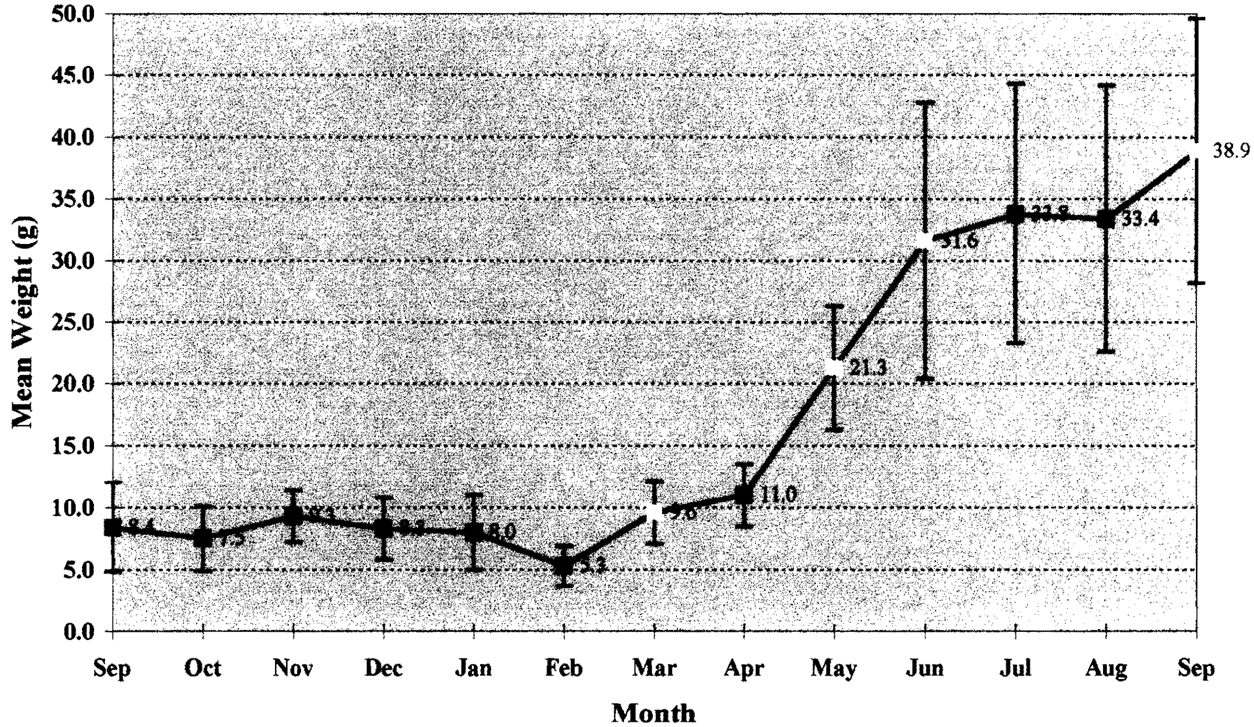

Figure 2. Mean weights (g) of trout collected from September 1996 to September 1997 in Little River, GSMNP. Vertical bars represent standard deviation. Yellow points indicate significant change from previous month.

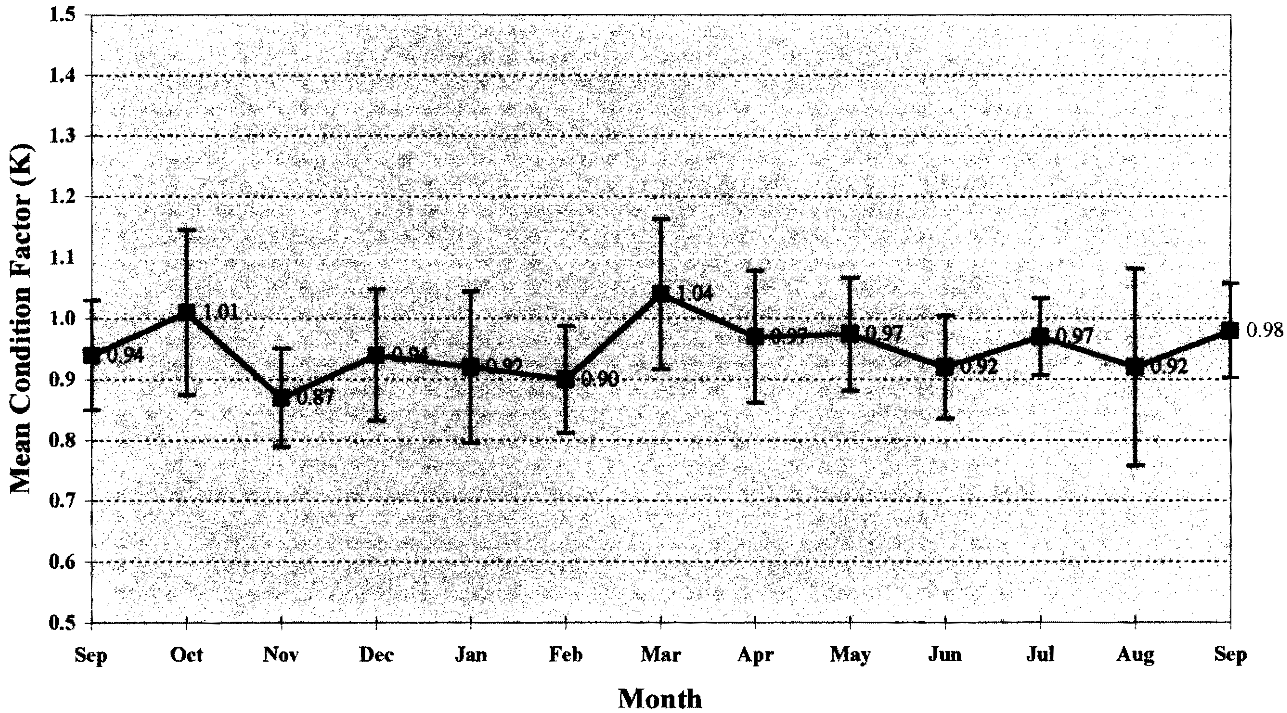

Figure 3. Mean condition (K) of trout collected from September 1996 to September 1997 in Little River, GSMNP. Vertical bars represent standard deviation. Green points indicate significant change from previous month.

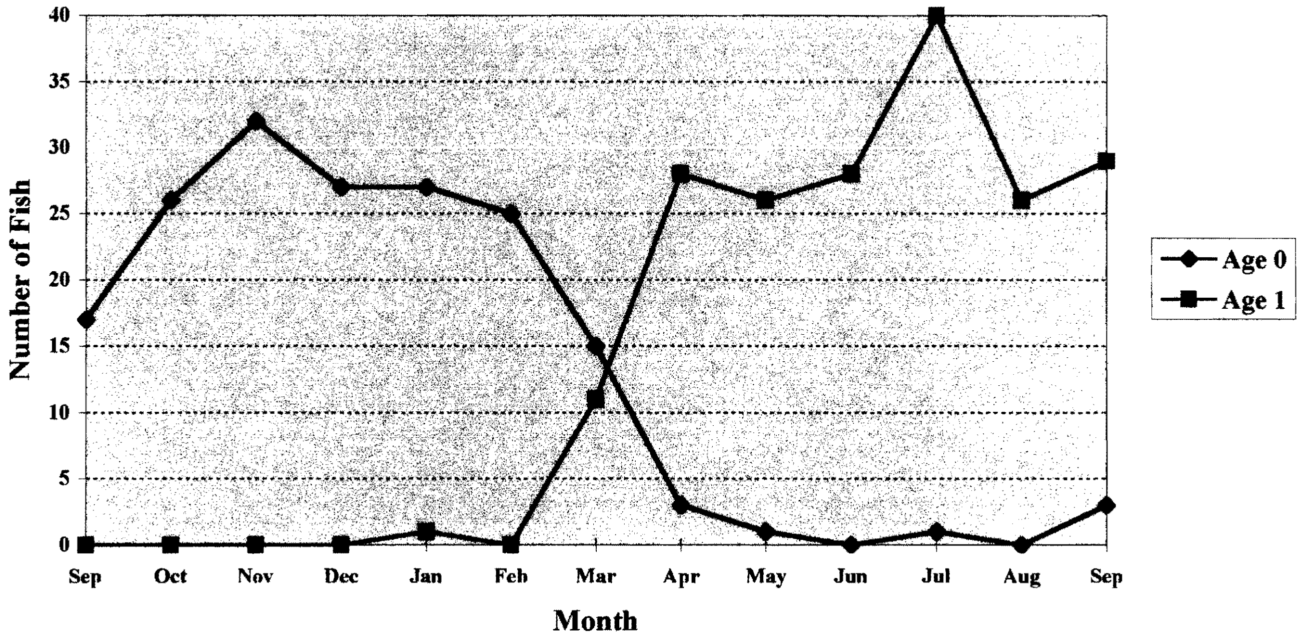

Figure 4. Age composition (determined by scales) of monthly samples of trout collected from September 1996 to September 1997 in Little River, GSMNP.

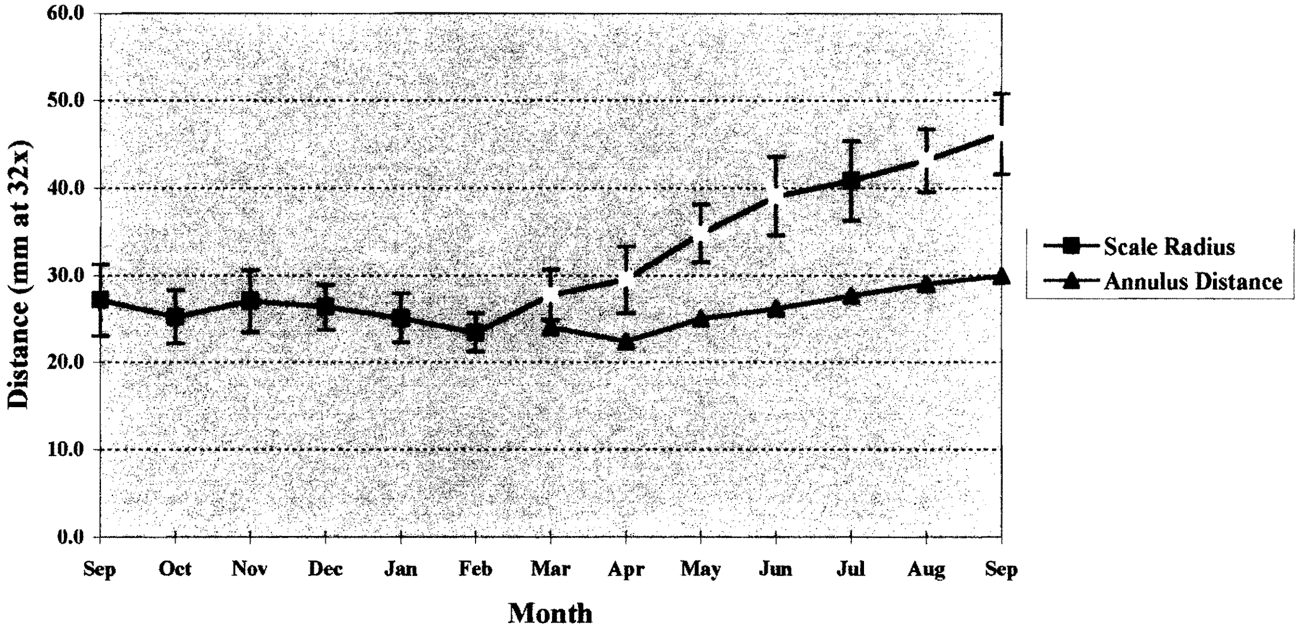

Figure 5. Mean scale radii and annular distances of scales collected from September 1996 to September 1997 in Little River, GSMNP. Vertical bars show standard deviation. Yellow and green points mark significant changes.

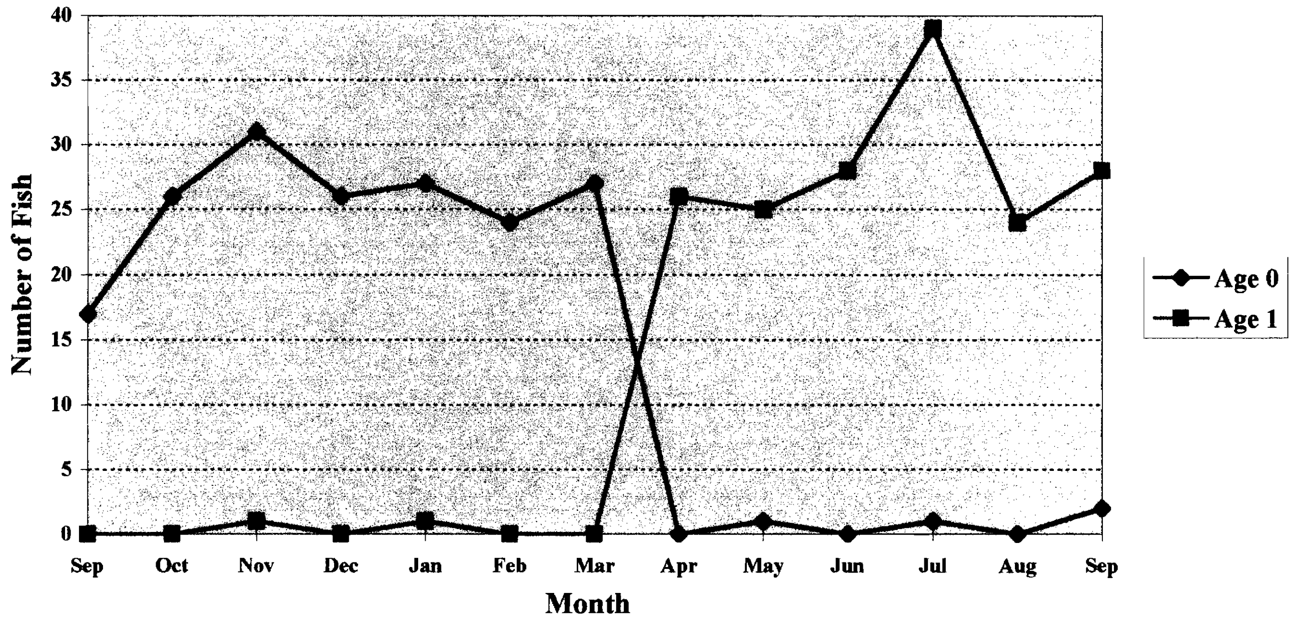

Figure 6. Age composition (determined by otoliths) of monthly samples of trout collected from September 1996 to September 1997 in Little River, GSMNP.

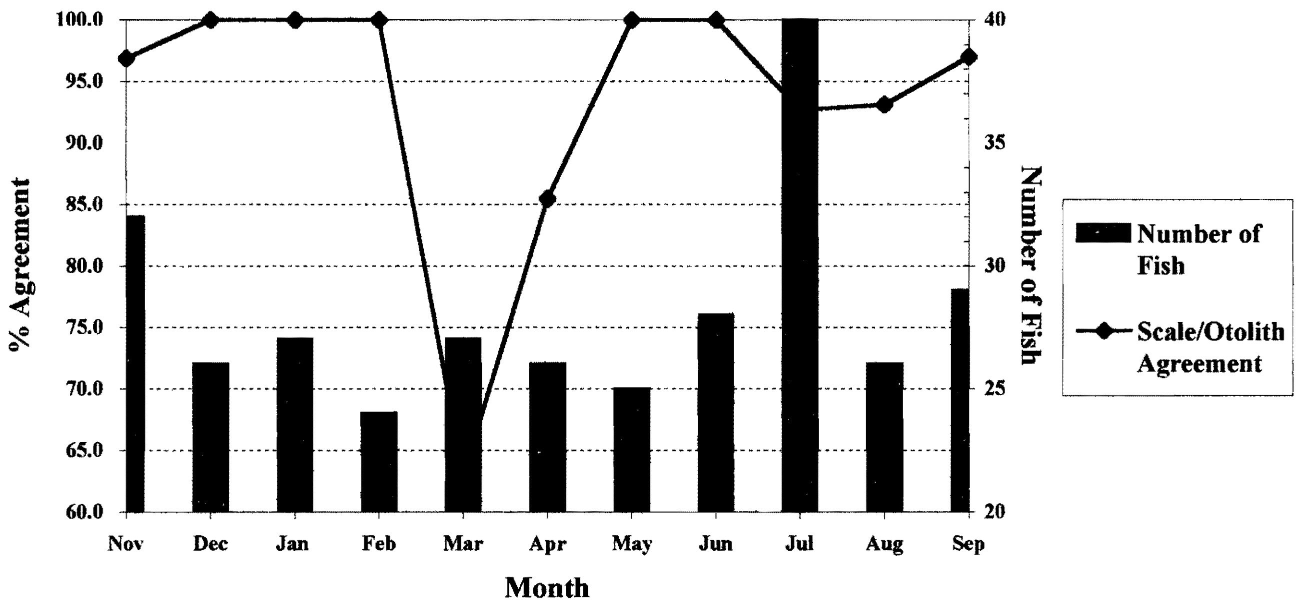

Figure 7. Monthly percent agreement between scale age and otolith age of fish collected from September 1996 to September 1997 in Little River, GSMNP.